Multi-Particle Effects

- Examples:
  - space-charge (beam self force)
  - Beam-beam (for colliders)
  - Electron cloud

- For a self-consistent model, we need to calculate forces at every step
  - Beam changes as it goes through the lattice
  - Beam changes from the multi-particle effects

Particle Force calculation

- Brute force: particle-particle method

  – This is an order N^2 calculation

- Particle-Mesh calculation

  – Distribute particles on a mesh, calculate forces, etc, on this mesh

  – This is an order $N \log(N)$ calculation

- Particle-Particle-Particle-Mesh

  – Hybrid (PP for close neighbors, PM for further away)

Particle Mesh Steps

- ## Define a grid
  - Grid spacing should match model requirements. Multi-scale or adaptive will do better

- ## Assign charge to the mesh
  - Various schemes

- ## Solve field equations on the mesh
  - Various solvers

- ## Calculate mesh-defined force field

- ## Interpolate to find force on particles
  - Various schemes

Various comments...

- Charge deposition scheme and force interpolation scheme should be the same, or in general self-forces (particle on itself) will be generated

- Solvers: a very rich field. We will touch on finite difference/linear algebra and FFT.

More comments

- In general, for beams it is sufficient to solve the Poisson equation

    – Transform to the beam rest frame

    – For two beams (beam-beam) take turns on each beam's frame

- For plasmas, you need fully EM solvers.